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Conversion from Corn to Grassland Provides Economic and Environmental Benefits to a Maryland Beef Farm

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Abstract

Beef producers must consider management strategies and technologies for reducing potential adverse environmental effects of their farms while maintaining or improving profit. One choice is between using perennial grassland or corn as the primary crop on the farm for feed production. Perennial grassland production systems are generally regarded as more favorable due to reduced nutrient losses to the environment and potential human health benefits through improvements in meat fatty acid composition. Simulation of an Angus cattle-producing farm of 325 acres in northeastern Maryland illustrated that the conversion of the farm from a corn and permanent pasture system to all perennial grassland with the use of more intensive rotational grazing has provided both environmental and economic benefits. Simulated nitrogen loss through ammonia volatilization was increased 21%, but nitrate leaching was reduced 56%, denitrification loss was reduced 50%, and surface runoff loss of P was reduced 75%. This conversion also increased the annual net return of the farm by $18,800 by eliminating the greater machinery, fuel, seed, fertilizer, and chemical costs incurred in corn production.

Introduction

Major constraints or challenges to the long-term sustainability of livestock operations are profitability and environmental impact. As the beef industry has adjusted to a more global market, the real price of farm produce has declined relative to most production costs. Thus, farms continue to be driven toward more efficient production to remain profitable. Along with this economic pressure are the growing concerns over the impact of farms on the environment. Governmental guidelines and regulations related to nutrient management are encouraging, and in some cases forcing, producers to consider management changes to meet these concerns.

Farm nutrient losses of most concern are N and P. Gaseous emission of N (primarily as ammonia) begins soon after urine and feces are excreted and it continues until that manure is incorporated into soil. Incomplete decomposition through nitrification and denitrification also creates and emits nitrous and nitric oxides into the atmosphere during some manure handling and storage practices and following soil incorporation. These gaseous emissions contribute to environmental problems such as acid rain, over-fertilization of ecosystems, and global warming. Ammonia in the atmosphere also contributes to the formation of very small airborne particles which are a human health concern. Over-application of N to soil can lead to excessive leaching causing health risks associated with high nitrate levels in groundwater. Runoff losses of P, and sometimes N, contribute to the eutrophication of surface waters which damage aquatic life and increase the processing costs for obtaining potable water.

Pasture and cropping practices have an important role in farm management with both economic and environmental implications. Harvested and grazed grassland normally provides a major feed source in beef production. Corn can also be an important feed because of the higher forage yields relative to grassland and the greater energy contents obtained when harvested as either silage or grain. Benoit and Simon (1) found that permanent grassland production resulted in lower nitrate leaching losses than corn silage production. Compared to permanent pastures, annual crops such as corn are prone to nitrate leaching since there is no uptake of residual N from the soil in the fall through early spring period. Furthermore, permanent grassland is associated with the preservation of soil organic matter thus increasing water-holding capacity, improving soil fertility, decreasing soil erosion, and increasing the sequestration of carbon from the atmosphere (4). Studies also indicate that beef produced from pasture may have beneficial consequences for human health due to improvements in meat fatty acid composition (10). There are also disadvantages to grass. Manure applied to grassland cannot be incorporated into the soil, which may increase volatile losses and surface losses of water-soluble nutrients. In pastures, urine and feces are deposited in highly concentrated spots where nutrients are not efficiently recycled in crops and thus are more prone to leaching loss (12).

When considering cropping changes, producers and those advising producers must consider the impacts occurring throughout the farm and between the farm and its environment. This process requires the integration of considerable information. Whole-farm simulation provides a tool that can assist in this type of comprehensive assessment by considering all the major components, the most important interactions among these components, and their impacts on farm performance, profitability, and the environment.

A simulation study was done to compare the long-term environmental and economic benefits of perennial grassland- and corn-based beef production systems on a farm in the mid-Atlantic region. Specific objectives were to (i) simulate an actual grassland-based Angus beef producing farm in Maryland using a whole-farm model, (ii) verify the model by comparing simulated grassland and beef production data to actual farm records, and (iii) compare simulated long-term nutrient losses and economic performance of this production system to those of a corn-based system previously used on this farm.

Farm Production Systems

The farm is located in an environmentally sensitive area near the Chesapeake Bay. Many management changes have been made to reduce potential nutrient losses from this farm. The primary change, made in the early 1990s, was the conversion from a corn-based production strategy to all perennial grassland. In the 1970s and 1980s, corn silage and grain produced on the farm provided feed for the herd along with continuously stocked permanent pastures. Now the corn land has been converted to renovated grassland that is rotationally stocked along with the permanent pasture to supply all of the required forage. Since the conversion, the producer has recorded grassland production data, which provides useful information for model calibration and evaluation.

The farm consists of 325 acres of grassland on Chester silt loam and Gleneld loam soils. The land is moderately sloping with slopes of 8 to 15%. With the current production system, 110 acres are renovated on about a 10-year cycle and the remainder is in permanent pasture of mostly tall fescue (Table 1). Renovated pastures are seeded in orchard grass or tall fescue interseeded with red clover or alfalfa. The predominant tall fescue cultivar is Kentucky 31. Because of the high proportion of legumes maintained in the pastures, endophyte toxicity has not been a problem. A no-till seeding operation is used to establish pastures at a cost of $20/acre. Up to two thirds of the grassland is harvested in the spring and early summer. About half of this forage is preserved as bale silage with the remainder stored and used as dry hay. Remaining grassland in the spring and summer and all grassland in the fall are rotationally stocked with a portion stockpiled for winter grazing (Fig. 1).

Table 1. Description of two production systems simulated on a 325 acre beef cattle farm in northeastern Maryland[x].

	Intensive grassland system	**Corn and permanent pasture system**
Land and nitrogen use		
Permanent grassland area (acre)	215	215
Renovated grassland area (acre)	110	0
Fertilizer applied to grassland (lb N/acre)	20	25
Corn area (acre)	0	110
Fertilizer applied to corn (lb N/acre)	0	120
Spring grazing area (acre)	185	215
Summer grazing area (acre)	285	215
Fall grazing area (acre)	325	215
Livestock		
Livestock Cows (head)	140	140
Replacement heifers (head)	37	37
Stocker cattle (head)	100	100
Finishing cattle (head)	70	70

[x] Farm information obtained through producer interviews and farm records.

Fig. 1. Angus cattle on the farm receive over 90% of their feed intake through grazed and conserved forage from perennial grass and legume pastures.

The herd typically consists of 140 registered pedigree Angus cows and progeny with about 25% of the cows replaced each year (Table 1). Replacement heifers calve in December and cows calve from January to March. Of the 100 stockers maintained on the farm, about 25 are sold each year as breeding bulls with 70 finished at 22 to 24 months of age. Cattle are not subject to implant or ionophore treatments. Most of the feed requirement is met with farm-produced forage, but corn grain is purchased for supplemental energy, primarily during the finishing of cattle. Minerals are also purchased to supplement all cattle.

Animals are wintered outside using structures consisting of two 50-ft by approximately 11-ft pads on either side of a feed bunk (Fig. 2). The pads slope toward a 30-ft by 30-ft pit for the collection and storage of manure. The cattle have access to "sacrifice paddocks" around these pads during the winter months. Manure collected from these feeding structures is removed in the spring and fall and surface-applied to the grassland.

Fig. 2. A feeding pad and manure storage facility constructed to improve feed use and reduce manure nutrient losses.

Forage production and use are carefully monitored by the producer using an "animal grazing days" measurement developed by the producer. With this technique, one animal unit is assumed to represent a 705-lb beef animal consuming 17.6 lb dry matter (DM) daily (3). All animals are converted to standard units by dividing their weight by 705 lb. Thus, the forage removed by grazing of each paddock is estimated as the total number of animal units multiplied by the number of days spent grazing. Harvested forage is included in the annual calculation with each 17.6 lb DM harvested representing one animal grazing day unit. In this way, the total annual forage yield for each unit of land is determined as the total number of animal grazing days times 17.6 lb DM/day divided by the area (Table 2).

Prior to the conversion to grassland, the 110 acres of renovated pasture were used to produce corn with the remaining permanent pasture land available for continuous grazing (Table 1). No grassland was harvested, so all forage was provided through grazing and corn silage production. Corn beyond that required for silage was harvested and fed as dried grain. Initially corn was established using a chisel plow tillage system; however, no-till establishment was practiced for several years prior to the conversion to all grassland.

Table 2. Comparison of simulated crop yields (ton DM per acre/year) to actual grassland data obtained from producer records and county average corn silage yields.

	Maximum	Minimum	Average	St. dev.
Intensive grassland system				
Renovated grassland[v]	3.82	3.01	3.45	0.25
Permanent pasture[v]	3.50	2.46	2.80	0.32
Total	3.48	2.90	3.10	0.20
Simulated pasture[w]	3.48	2.55	3.10	0.32
Corn and permanent pasture system				
Corn silage[x]	8.35	4.85	6.35	1.19
Simulated corn silage[y]	7.89	5.03	6.35	1.10
Permanent pasture[z]	2.52	1.77	2.02	0.25
Simulated pasture[w]	2.51	1.31	2.02	0.34

[v] Total pasture and harvested grassland yields recorded by the producer (1991 to 1998).

[w] Pasture yields predicted by the Integrated Farm System Model using historical weather data for Baltimore, MD (1991 to 1998).

[x] Harford county corn silage yields (1996 to 2004) reported by the Maryland Agricultural Statistics Service (5) increased by 10% to reflect better than average management.

[y] Corn silage yields predicted by the Integrated Farm System Model using historical weather data for Baltimore, MD (1996 to 2004).

[z] Continuously stocked, permanent pasture production and utilization was 72% of the current permanent pasture yield over these 8 years representing the effects of continuous stocking and suppressed pasture intake for cattle with access to corn silage (6,7) and to meet the feed utilization reported by the producer.

For the previous and current systems, cattle were marketed both as seedstock and finished animals. This primarily affected cattle prices (Table 3), but this also influenced the types of animals on the farm and the resulting feed use. For both production systems, finished cattle were finished in a feedlot. The current system relies upon bale silage and corn grain for feed during finishing, whereas corn silage provided the forage in the previous system. Based upon the producer's experience, about 15% more time is required for finishing with the current system, but cattle finish at similar weight, grade, and market value as that attained using corn silage and grain. For both systems, finished cattle were assumed to be processed and direct marketed by the producer as is currently practiced.

Table 3. Important initial costs and prices assumed for the analysis of feed production systems for a Maryland beef farm.

Parameter	Initial cost
Seed and chemicals for crop establishment	
Grassland	$118/acre
Corn	$90/acre
Pasture costs with grassland system	
Perimeter fence	$8000
Temporary fence	$2000
Watering facilities	$3000
Corn and permanent pasture system	
Perimeter fence	$5000
Temporary fence	$500
Watering facilities	$1000
Parameter	**Price**[x]
Corn grain	$120/ton DM
Corn silage	$72/ton DM
Grass hay	$120/ton DM
Soybean meal	$250/ton DM
N fertilizer	$0.45/lb N
P fertilizer	$0.30/lb P_2O_5
K fertilizer	$0.25/lb K_2O
Fuel	$2.25/gallon
Cows	$75/cwt
Finished cattle[y]	$92/cwt
Seedstock cattle	$195/cwt

[x] Prices were set to represent long-term relative prices in current value, which were not necessarily current prices.

[y] Finished cattle price was set to the producer's internal accounting price for the transfer of product to the processing and marketing portion of the business.

Simulation Analysis

Farm production systems were simulated using the Integrated Farm System Model (USDA-Agricultural Research Service, University Park, PA). This model simulates crop production, feed use, and the return of manure nutrients back to the land over many years of weather (Fig. 3) (9). Growth and development of grassland and corn crops are predicted from daily soil and weather conditions. Performance and resource use in manure handling, tillage, planting, and harvest operations are functions of the size and type of machines used and daily weather. Field drying rate, harvest losses, and nutritive changes in crops are related to the weather, crop conditions, and machinery operations used. Losses and nutritive changes following harvest are influenced by the characteristics of the harvested crops and the type and size of storage facilities used.

Feed allocation and animal response are related to the nutritive value of available feeds and the nutrient requirements of up to six animal groups making up the herd (suckling calves, weaned calves, stockers, finishing cattle, replacement heifers, and cows). Diets for an average animal in each group are formulated using a cost-minimizing linear program, which makes the best use of homegrown feeds and, if needed, purchased supplements (8). Protein, energy, and mineral requirements are determined using the Cornell Net Carbohydrate and Protein System, level 1 (2). Supplemental protein, P, or K fed, if any, is the difference between the requirement of each animal group and the sum of that contained in the feeds consumed.

Nutrient flows through the farm are modeled to predict potential nutrient accumulation in the soil and loss to the environment (9). The quantity and nutrient content of the manure produced is a function of the quantity and nutrient content of the feeds consumed. Volatile nitrogen losses occur from manure in the housing facility, during storage, and following field application, and from urine deposits during grazing. Leaching and denitrification losses from the soil are related to the rate of moisture movement and drainage from the soil profile as influenced by soil properties, rainfall, and the amount and timing of manure and fertilizer applications. Runoff losses of sediment and soluble P are a function of manure application and tillage practices as well as daily soil and weather conditions. A whole-farm balance of N, P, and K includes the importation of nutrients in feed and fertilizer and the export in animals, excess feed, and manure.

Simulated performance is used to determine production costs, income, and farm net return for each simulated year (9). A whole-farm budget is used where investments in equipment and structures are amortized over their economic life considering a real interest or discount rate. Resource requirements and production predicted by the model for each year are used to determine annual operating expenditures and incomes. The annual net return to management, labor, and unpaid factors is the sum of the incomes from the sale of animals and excess feeds minus operating costs for animal maintenance, feeding, feed production, and manure handling. This net return provides a measure of farm profit where tax incentives and other forms of government subsidies are not considered. By simulating and comparing production options, the long-term effects of production changes are measured including resource use, production efficiency, environmental impact, and profitability.

A feature of the model is the capability of adjusting forage growth to account for specific management and site characteristics (9). Thus, growth rates were calibrated to give the long-term average forage yields measured on the farm. With this calibration, the model did well in replicating the yield variability across years as measured on the farm from 1991 to 1998 (Table 2). When corn was used, the long-term average harvested corn silage yield was set at 10% above the average county yield (1996 to 2004) as recorded by the Maryland Agricultural Statistics Service (5). Yields were set higher than the county data to represent better than average management. The silage yield variability among simulated years was again similar to that of the recorded data (Table 2).

To simulate the continuously stocked permanent pasture in the corn based system, pasture production and utilization was adjusted to reflect the effects of continuous stocking and the suppressed pasture intake that occurs when cattle have access to corn silage (6,7). The proportion of legume in the canopy was reduced from an average of 25% to less than 10% to represent the effect of lower legume persistence under continuous grazing. Pasture utilization was reduced 10% along with a 10% greater loss due to trampling and fouling by the animals. Together, these effects reduced pasture production and use by 70% compared to the current permanent pasture with rotational grazing (Table 2). The simulated variability in production was similar to that estimated from the current permanent pasture, but the lowest production years were underestimated by up to 25% (Table 2). The energy content of the pasture was also reduced 5% to reflect more mature forage.

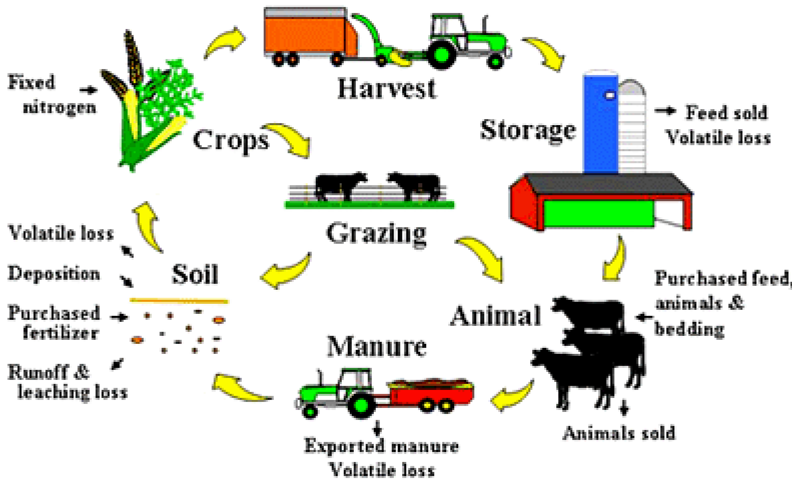

Fig. 3. The Integrated Farm System Model simulates the performance, environmental impact, and economics of beef production systems over many years of weather.

A Comparison of Production Systems

The two production systems were simulated over the same 25 years of historical weather data for Baltimore, Maryland (1980 to 2004) using the same land base. Farm parameters such as soil characteristics, animal numbers, feeding facilities, and prices were the same for both systems. Prices were set to represent long-term relative prices in current value, which were estimated from reported values over the past 5 years (Table 3). Parameters such as crop area, crop establishment procedures, harvest and storage methods, and pasture costs (Table 3) were varied to appropriately represent the two production systems.

Simulation of the current perennial grassland system showed that 92% of the total feed requirement for the herd was produced on the farm (Table 4). Grazed forage provided 54% of the average annual feed requirement. Feed purchases included minerals and the corn grain used to finish cattle. Nitrogen imported in feed and fertilizer along with legume fixed N was much greater than that leaving the farm in meat products. This extra N was lost through ammonia volatilization, nitrate leaching, and denitrification losses (Table 4). The farm maintained a long-term P balance with exported P in meat products equaling that imported in feed and fertilizer. With all of the land in perennial grassland and the use of good manure management practices, P runoff loss from the farm was relatively low.

Simulation of the corn and permanent pasture system formerly used on the farm showed that this system was able to provide 97% of the feed requirement of the herd (Table 4). Due to weather influences, between 60 and 100% of the corn land was harvested as silage on any given year with the remainder harvested as grain. All of the grain needs were met with some extra sold during years with the best growing conditions. Because of the lower protein content in corn silage, more purchased protein was required compared to the current grassland system (7). Protein needs of the animals were more efficiently met with corn silage, which allowed lower N excretion in manure and thus lower ammonia N emission (Table 4). Manure N applied to the annual corn crop was more susceptible to loss over the winter and spring seasons which led to greater leaching and denitrification losses. Nitrate leaching is considered to pose an environmental hazard when N concentrations in groundwater are over 10 ppm (11). With the corn-based system, the whole-farm average annual N level in leachate leaving the root zone was approaching this level (Table 4).

Table 4. Average annual feed production, feed use, and nutrient balance for two simulated production systems on a beef farm in northeastern Maryland.

	Intensive grassland system	**Corn and permanent pasture system**
Grazed forage consumed (ton DM)	526	488
Grass hay and silage production (ton DM)	390	0
Grass hay sold (ton DM)	16	0
Corn silage production (ton DM)	0	451
Corn grain production (ton DM)	0	69
Corn grain purchased [sold] (ton DM)	67	[4]
Protein and minerals purchased (ton DM)	8	32
Nitrogen imported (lb/acre)	125	116
Nitrogen exported (lb/acre)	20	19
Nitrogen lost by volatilization (lb/acre)	40	33
Nitrogen lost by leaching (lb/acre)	14	32
Nitrogen lost by denitrification (lb/acre)	7	14
Nitrogen concentration in leachate (ppm)	3.3	9.9
Phosphorus imported (lb/acre)	4.5	10.0
Phosphorus exported (lb/acre)	4.3	4.8
Phosphorus loss in runoff (lb/acre)	0.2	0.7
Soil phosphorus buildup (lb/acre)	0.0	4.5

The use of a chisel plow system for corn establishment caused greater erosion and more than a three-fold increase in P runoff loss compared to grassland. Use of no-till establishment, as was practiced for several years prior to the conversion to all grassland, provided 58% less soil erosion and 39% less P runoff loss (*data not shown*), but this loss was still over twice that predicted for the current grassland system. The farm was not able to maintain a long-term P balance with the corn-based production system. Since much of the manure was deposited by grazing animals, there was an accumulation of P on the permanent pastures with a P deficit on some of the corn land further away from the barn where no manure was applied. This deficit was met with purchased fertilizer.

Simulation of the current grassland system showed that the annual revenue from animal sales exceeded production costs providing an annual net return to management, labor, and other unaccounted costs of $65,700 (Table 5). This net return was $18,800 per year greater than that found for the prior corn and permanent pasture system simulated over the same years of weather. This difference was primarily because of greater feed production costs using corn. Greater production costs were because of more equipment operations and the higher seed, chemical, and fertilizer costs incurred in corn production. Even though corn grain purchase was eliminated, purchased feed cost was similar to that of the grassland system because of greater use of higher cost protein supplement feeds.

Table 5. Average annual financial performance of the two simulated production systems for a beef cattle farm in northeastern Maryland.

	Intensive grassland system	Corn and permanent pasture system
Revenue from animal sales ($)	153,700	153,700
Production costs ($)		
Feed production[x]	46,900	67,800
Net purchased feed	11,500	10,300
Manure handling	6,100	5,100
Animal facilities	2,000	2,000
Livestock expenses	18,100	18,100
Property tax	3,400	3,500
Total	88,000	106,800
Net return to management and labor ($)	65,700	46,900

[x] Feed production costs include annual costs for machinery ownership and operation, fuel, custom operations, seed, pesticides, fertilizer, fence, watering facilities, feed and machinery storage, and equipment used in feeding.

Application of the Results

Like most farms, this farm is unique. Farm characteristics such as the use of registered cattle, the combined production of seedstock and finished cattle, and the high turnover of cows in the herd all influence the specific results generated by the simulation model. These factors have similar effects on both production systems though, so relative changes between systems should be minor. Factors such as soil characteristics, terrain, and climate affect corn and grassland productivity, which will have some influence on the environmental and economic comparisons. Other factors such as stocking rate, calving date, and assumed prices also influence the economic comparisons. Thus, the specific results of this analysis cannot be directly applied to other farms.

Although specific simulation values will vary, the overall comparison of beef production systems relying primarily upon grassland or corn production should generally apply to similar beef producing farms throughout the mid Atlantic and northeastern regions of the US. These general results are that the use of intensively managed perennial grassland can improve nutrient management, reduce nutrient losses to the environment, and improve profitability compared to the use of corn-based production systems. For those interested in further evaluation of specific farm production systems, a Windows version of the model is available for download (http://ars.usda.gov/naa/pswmru).

This simulation study demonstrates the potential benefits for maximizing the use of perennial grassland in beef production. Although producers should be encouraged to consider greater use of grassland, other factors may deter a shift to this management strategy. Some producers may have made large investments in machinery and buildings in adapting their methods of production to corn silage systems and, therefore, will be reluctant to change. In addition, farmers who have not previously operated with a focus on rotational grazing will need to acquire the relevant skills to facilitate the conversion. However, for those willing to consider this change, the benefits are worth the effort of conversion.

Conclusion

Simulation of a beef producing farm in Maryland showed that converting from a corn-based production system to a perennial grassland system with rotational grazing provided both environmental and economic benefits. Simulated N loss through ammonia volatilization increased some, but nitrate leaching, denitrification loss, and surface runoff loss of P were reduced substantially. The conversion increased the annual net return of the farm by $18,800 by eliminating the greater machinery, fuel, seed, fertilizer, and chemical costs incurred in corn production. These potential benefits should encourage more producers and those advising producers in the northeast and mid Atlantic regions to consider greater use of grassland in beef production systems where corn currently has a major role.

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